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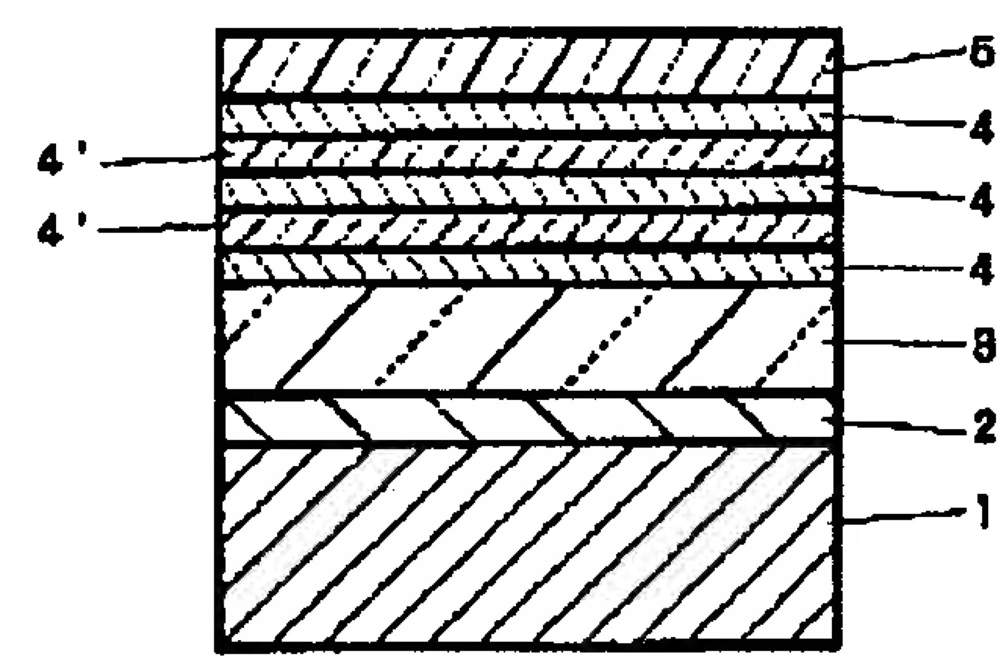
(54) **GALLIUM NITRIDE COMPOUND SEMICONDUCTOR LIGHT EMITTING ELEMENT**

(57) Abstract:

PURPOSE: To enable a light emitting layer to be enhanced in crystallinity and emission output by a method wherein a multilayered film is composed of layers specified in thickness.

CONSTITUTION: A buffer layer 2 is made to grow on a sapphire substrate 1, and an N-type Si-doped GaN layer 3 is grown thereon. Thereafter, an $In_{0.2}Ga_{0.8}N$ layer 4 is grown as a well layer, and furthermore an $In_{0.04}Ga_{0.96}$ layer 4' is grown as a barrier layer. The layers 4 and 4' are alternately laminated to form a multilayered film by repeatedly carrying out the above processes. The layers 4 and 4' forming a multilayered film are so set as to be as thick as 5 to 50Å. Then, a P-type Mg-doped GaN layer 5 is made to grow, and then the substrate 1 is taken out of a reaction vessel and annealed to lessen the uppermost P-type GaN layer more in resistance. The P-type GaN layer 5 and a multilayered film of a wafer obtained as above are partially etched to make the N-type GaN layer exposed, and an ohmic electrode is provided to a P-type GaN layer and an N-type GaN layer respectively.



[Claim(s)]

[Claim 1] Between n mold gallium nitride system compound semiconductor layer and p mold gallium nitride system compound semiconductor layer It is the gallium nitride system compound semiconductor light emitting device which possesses the multilayers layer to which the laminating of the InXGa1-XN (however, X 0< X<1) layer from which X value differs was carried out by turns as a luminous layer. Each thickness of the InXGa1-XN layer which constitutes said multilayers layer is a gallium nitride system compound semiconductor light emitting device characterized by being the range of 5A - 50A.

[Claim 2] It is the gallium nitride system compound semiconductor light emitting device according to claim 1 characterized by for said n mold gallium nitride system compound semiconductor layer consisting of GaYAl1-YN (however, Y 0< Y<=1), and said p mold gallium nitride system compound semiconductor layer consisting of GaZAl1-ZN (however, Z 0< Z<=1).

[Claim 3] X value of said InXGa1-XN layer is a gallium nitride system compound semiconductor light emitting device according to claim 1 characterized by being the range of 0< X<0.5.

[Detailed Description of the Invention]

[0001]

[Industrial Application] This invention relates to the light emitting device which used the gallium nitride system compound semiconductor.

[0002]

[Description of the Prior Art] Since gallium nitride system compound semiconductors, such as GaN, GaAlN, InGaN, and InAlGaN, have direct transition and a band gap changes to 1.95eV - 6eV, promising ** of light emitting diode, the laser diode, etc. is carried out as an ingredient of a light emitting device. to the light emitting device using current and this ingredient, p mold dopant was doped on n mold gallium nitride system compound semiconductor -- high -- the so-called blue light emitting diode of the metal-insulator-semiconductor structure which carried out the laminating of the gallium nitride system compound semiconductor of i mold [****] is known.

[0003] Generally, the light emitting device of metal-insulator-semiconductor structure had the very low radiant power output, and it was still inadequate for putting in practical use. high -- i mold [****] -- low -- it considers as p mold [****] and the technique which carries out electron beam irradiation to i mold gallium nitride system compound semiconductor layer is indicated in JP,3-218325,A as a technique for realizing the light emitting device of the p-n junction which raised the radiant power output. moreover, the thing which we do above 400 degrees C by Japanese Patent Application No. No. 357046 [three to] for annealing of the i mold gallium nitride system compound semiconductor layer -- low -- the technique used as p mold [****] was proposed.

[0004]

[Problem(s) to be Solved by the Invention] Although, as for the light emitting device using a gallium nitride system compound semiconductor, metal-insulator-semiconductor structure and p-n junction both sides to research was advanced, the light emitting device of the radiant power output of gay structure using the p-n junction of GaN was also still inadequate for putting in practical use by there being nothing in several microwatts - dozens of microwatts, for example. Therefore, this invention is made in view of such a situation, and the place made into the purpose is to raise further the radiant power output of a gallium nitride system compound semiconductor light emitting device.

[0005]

[Means for Solving the Problem] It found out that the above-mentioned problem was solvable by our making a gallium nitride system compound semiconductor light emitting device the double hetero structure where p-n junction was used, and making the luminous layer into the multilayers structure using the gallium nitride system compound semiconductor of specific thickness further. Namely, the gallium nitride system compound semiconductor light emitting device of this invention Between n mold gallium nitride system compound semiconductor layer and p mold gallium nitride system compound semiconductor layer It is the gallium nitride system compound semiconductor light emitting device which possesses the multilayers layer to which the laminating of the InXGa1-XN (however, X 0< X<1) layer from which X value differs was carried out by turns as a luminous layer. Each thickness of the InXGa1-XN layer which constitutes said

multilayers layer is characterized by being the range of 5A - 50A.

[0006] In the gallium nitride system compound semiconductor light emitting device of this invention, the layer which grew as n mold dopants, such as Si, germanium, Te, and Se, were doped to the gallium nitride system compound semiconductor of non dopes (additive-free), such as GaN, GaAlN, InGaN, and InAlGaN, or the gallium nitride system compound semiconductor of a non dope and n mold property was shown in it can be used for n mold gallium nitride system compound semiconductor layer. the duality set to GaYAl1-YN (however, Y 0< Y<=1) rather than especially n mold gallium nitride system compound semiconductor used the presentation as the gallium nitride system compound semiconductor containing an indium -- since n mold crystal the direction made into mixed crystal or the gallium nitride aluminum of 3 yuan mixed crystal excelled [crystal] in crystallinity is obtained, a radiant power output increases and it is still more desirable.

[0007] Moreover, the layer which grew as p mold dopants, such as Zn, Mg, Cd, Be, and calcium, were doped to the gallium nitride system compound semiconductor of the non dope described above in p mold gallium nitride system compound semiconductor layer and p mold property was shown in it can be used. the duality which also set this p mold gallium nitride system compound semiconductor layer to GaZAl1-ZN (however, Z 0< Z<=1) rather than it used especially that presentation as the gallium nitride system compound semiconductor containing an indium -- the direction made into mixed crystal or the gallium nitride aluminum of 3 yuan mixed crystal -- crystallinity -- good -- more -- low -- since p mold crystal [****] becomes is easy to be obtained, it is desirable. Furthermore, annealing processing which indicates p mold gallium nitride system compound semiconductor layer as a means to form low resistance further, to above mentioned Japanese Patent Application No. No. 357046 [three to] may be performed. A radiant power output can be raised more by forming low resistance.

[0008] It is necessary to make an InXGa1-XN layer into the multilayers layer structure which carried out the laminating of the InXGa1-XN (however, X 0< X<1) layer from which X value differs by turns, and to adjust each thickness of the InXGa1-XN layer which constitutes the multilayers to the range of 5A - 50A. While multilayers serve as quantum well structure and increase a radiant power output by carrying out the laminating of the

InXGa1-XN layer from which X value differs by turns, lattice constant non-** with n mold gallium nitride system compound semiconductor and p mold gallium nitride system compound semiconductor can be eased. Moreover, rather than what did not make multilayers but was formed in the single InGaN layer, the lattice defect under crystal decreases and crystallinity improves. Furthermore, a radiant power output can be raised by adjusting the thickness of an InXGa1-XN layer to the range of 5A - 50A. Because, since the lattice defect of the InXGa1-XN layer which constitutes multilayers by adjusting thickness to this range can be lessened and crystallinity improves, a radiant power output increases. The thickness of an InXGa1-XN layer can be adjusted by adjusting the flow rate of the source of Ga which is material gas as it is the growth approach which used for example, the MOCVD method, and adjusting growth time amount. Moreover, the presentation ratio of an InXGa1-XN layer can be adjusted by adjusting the quantity of gas flow or growth temperature of the source of In which is material gas. Furthermore, it cannot be overemphasized that n mold dopant and p mold dopant may be doped and grown up into an InXGa1-XN layer.

[0009] As for X value of each InXGa1-XN layer, it is desirable to adjust to the range of $0< X<0.5$. Since the light emitting device excellent in luminous efficiency becomes the InXGa1-XN layer X value excelled [layer] in crystallinity 0.5 or more is hard to be obtained, and is hard to be obtained, as for X value, less than 0.5 are desirable. Moreover, in order to realize current and the blue light emitting device which is not put in practical use, it is necessary to adjust to the above-mentioned range.

[0010]

[Function] For example, in the case of the light emitting device of the double hetero structure which carried out the laminating of an n mold GaN layer, an Inof 100A of thickness0.2Ga0.8N layer, and the p mold GaN layer to order, the lattice constant of GaN is about 3.54A, and, as for the lattice constant of about 3.19A and InN, has about 2.2% of lattice constant irregular ** of an interface (a GaN layer and In0.2Ga0.8N layer) by the light emitting device of this structure. For this reason, since the lattice defect by misfit occurs in an interface (a GaN layer and In0.2Ga0.8N layer) and the In0.2Ga0.8N layer crystallinity which is a luminous layer worsens, it becomes the cause by which a radiant

power output declines.

[0011] An In0.2Ga0.8N layer as for example, a well layer like this invention here However, the In0.2Ga0.8N layer 3 layer of 20A of thickness, The laminating of In0.04Ga0.96N layer two-layer [of 20A of thickness] is carried out by turns as a barrier layer. When it considers as the multilayers of the quantum well structure of the 100A of the total thickness of a luminous layer (that is,) The InXGa1-XN layer which are the light emitting device structure of an n mold GaN layer + well layer + barrier layer + well layer + barrier layer + well layer +p mold GaN layer and a luminous layer turns into an In0.12Ga0.88N layer as an average presentation, serves as 1.3% of lattice constant irregular **** of an interface with a GaN layer, and is eased. And In0.2Ga0.8N layer [which is a well layer] since light is emitted by the way, luminescence wavelength hardly changes. Therefore, since the crystallinity of the part and a luminous layer improves since lattice constant irregular ****** is carried out and an InGaN layer with few [as a whole] lattice defects is made with a luminous layer when the whole multilayers are made into one luminous layer, a radiant power output increases.

[0012] When each thickness of multilayers is made the same at drawing 2 in the above-mentioned light emitting device (n mold GaN layer +In0.2Ga0.8 N+In0.04Ga0.96 N+In0.2Ga0.8 N+In0.04Ga0.96 N+In0.2Ga0.96 N+p mold GaN layer), the relation between the thickness and the relative radiant power output of a light emitting device is shown. As shown in this drawing, the light emitting device which makes a luminous layer the multilayers which carried out the laminating of the InXGa1-XN layer which made thickness 5A - 50A has 90% or more of radiant power output, and if out of range, it is in that inclination for an output to decline rapidly. The reason is considered that an output will decline since a lattice defect becomes easy to be made into one InXGa1-XN layer if the InXGa1-XN layer of a thick film is made into multilayers as described above.

[0013]

[Example] Below by metal-organic chemical vapor deposition, how to manufacture the gallium nitride system compound semiconductor light emitting device of this invention is stated.

[0014] After arranging [example 1] silicon on sapphire 1 in a reaction container and

cleaning silicon on sapphire 1, growth temperature is set to 510 degrees C, hydrogen is used as carrier gas, ammonia and TMG (trimethylgallium) are used as material gas, and the buffer layer 2 which consists of GaN on silicon on sapphire is grown up by about 200A thickness.

[0015] Only TMG is stopped after buffer layer 2 growth, and temperature is raised to 1030 degrees C. If it becomes 1030 degrees C, similarly, TMG and ammonia gas will be used for material gas, silane gas will be used for dopant gas, and 4 micrometers of n mold GaN layers 4 which doped Si will be grown up.

[0016] Material gas and dopant gas are made as a stop after n mold GaN layer 4 growth, temperature is made into 800 degrees C, carrier gas is changed to nitrogen, and In0.2Ga0.8N layer 4 [20A] is grown up as a well layer, using TMG, TMI (trimethylindium), and ammonia as material gas. Next, In0.04Ga0.96N layer 4' is grown up by 20A thickness as a barrier layer by reducing the flow rate of TMI to one fifth. This actuation is repeated, and by 20A thickness, In0.2Ga0.8N layer 4 is grown up into the 1st, and it grows up each into the 2nd multilayers of In0.04Ga0.96N layer 4' and the 100A of the total thickness which made it In0.04Ga0.96N layer 4' In0.2Ga0.8N layer 4 and the 4th, and made the laminating of In0.2Ga0.8N layer 4 to the 5th by turns the 3rd.

[0017] Next, material gas grows up a stop and 0.8 micrometers of p mold GaN layers 5 which doped Mg, using Cp2Mg (magnesium cyclopentadienyl) as TMG, ammonia, and dopant gas as material gas by raising temperature to 1020 degrees C again.

[0018] A substrate is picked out from a reaction container after p mold GaN layer 5 growth, annealing equipment performs the inside of nitrogen-gas-atmosphere mind, annealing is performed for 20 minutes at 700 degrees C, and the p mold GaN layer of the maximum upper layer is further formed into low resistance. The sectional view showing the structure of the light emitting device obtained as mentioned above is shown in drawing 1 .

[0019] After having removed a part of p mold GaN layer 5 of a wafer, and multilayers layer obtained as mentioned above by etching, having exposed the n mold GaN layer 3, preparing the ohmic electrode in the p mold GaN layer and the n mold GaN layer and cutting into the chip of 500-micrometer angle, when it considered as light emitting diode according to the conventional method, the radiant power output had reached practical use

level enough with 800 microwatts and the luminescence wavelength of 410nm in 20mA.

[0020] In the [example 2] example 1, when increased each growth time amount of a multilayers layer 2.5 times, and the 50A and In0.04Ga0.96N layer was grown up by 50A thickness in the In0.2Ga0.8N layer and also light emitting diode was obtained similarly, the radiant power output was 410nm in 720 microwatts and luminescence wavelength in 20mA.

[0021] In the process into which the n mold GaN layer 3 of the [example 3] example 1 and the p mold GaN layer 5 are grown up Add TMA (trimethylaluminum) and it is newly grown up into material gas. When made the n mold GaN layer into the n mold Ga0.9aluminum0.1N layer which similarly doped Si, and the p mold GaN layer was made into the p mold Ga0.9aluminum0.1N layer which similarly doped Mg and also light emitting diode was obtained similarly, it was almost equivalent to the example 1 also with a radiant power output and luminescence wavelength.

[0022] In the [example 1 of comparison] example 1, when increased each growth time amount of a multilayers layer 3 times, and the 60A and In0.04Ga0.96N layer was grown up by 60A thickness in the In0.2Ga0.8N layer and also light emitting diode was obtained similarly, in 20mA, the radiant power output was 360 microwatts.

[0023] In the [example 2 of comparison] example 1, when the single In0.2Ga0.8N layer was grown up by 100A thickness instead of growing up a multilayers layer and also light emitting diode was obtained similarly, in 20mA, it was 420nm in 180 microwatts of radiant power outputs, and luminescence wavelength.

[0024]

[Effect of the Invention] As explained above, since the gallium nitride system compound semiconductor light emitting device of this invention is made into terrorism structure to the double using p-n junction and is made into the multilayers which consist of an InXGa1-XN layer of the thickness which had the luminous layer limited further, misfit with n mold gallium nitride system compound semiconductor layer and p mold gallium nitride system compound semiconductor layer becomes small, and its crystallinity of the whole luminous layer improves. Thereby, a radiant power output can improve by leaps and bounds, and a gallium nitride system compound semiconductor light emitting device can be made even

into sufficient practical use level.

[Brief Description of the Drawings]

[Drawing 1] The type section Fig. showing the structure of the light emitting device concerning one example of this invention.

[Drawing 2] Drawing showing the relation between each thickness of the multilayers in the light emitting device concerning one example of this invention, and the relative radiant power output of a light emitting device.

[Description of Notations]

1 ..... Silicon on Sapphire

2 ..... GaN Buffer Layer

3 ..... N Mold GaN Layer

4 ..... $In_{0.2}Ga_{0.8}N$ Layer

4' ..... $In_{0.04}Ga_{0.96}N$ layer

5 ..... P Mold GaN Layer